Complications From Total Hip Replacement With the Use of Acrylic Cement

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SURVEILLANCE of infections presupposes that one can adequately define criteria for presence of an infection. The classic findings of purulent drainage, fever, and isolation of a virulent organism with a short incubation period often makes the decision relatively easy. However, the hospitalization of patients with underlying diseases and therapies that may predispose them to infection, the use of foreign bodies as implants that may produce allergic reactions, and the recognition that organisms once considered to be "nonpathogenic" may become pathogenic under certain conditions, with protracted incubation periods, all make it difficult to adequately develop criteria for infections seen in hospitals. These problems have been seen in patients with postoperative artificial valve endocarditis due to coagulase-negative staphylococci or diphtheroids and post central nervous system shunt infection with coagulase-negative staphylococci (*1, 2*).

We have noted similar difficulties in developing criteria for postoperative wound infections in patients undergoing total hip replacements in which acrylic cement is used, and we describe our experience in this report.

Total hip replacement with the use of acrylic cement is a procedure reserved for patients who have severe and ofttimes disabling pain and marked destruction of their hip joints (*3–5*). The usual cause of the underlying disease is degenerative osteoarthritis, rheumatoid arthritis, or avascular necrosis. Self-curing acrylic cement is a mixture of powder and liquid which hardens into a polymer with a marked exothermic reaction that may create temperatures up to 90° C. (*5*). The presence of acrylic cement leads to two possible reactions: (*a*) an allergic reaction to the material itself and (*b*) local destruction of tissue, which may provide a necrotic focus for the development of an infection.

Charnley initially reported a wound infection rate of 8.9 percent in more than 190 total hip replacements with the use of acrylic cement. He noted certain unusual features of infections and reported (*a*) a tendency for infections to manifest themselves late after surgery and (*b*) a tendency for these infections to be "sterile." Furthermore, he noted a falling rate for deep wound infections, from 8.9 percent in 1959 to 0.5 percent in 1969, which he attributed to filtered forced air within the operating room and improved wound closure. However, no simultaneous control group was studied (*5–8*).

The referring physician must know the total risk of a given operation before he can make a reasonable evaluation of the patient as a possible candidate for the procedure. In addition, diagnostic and therapeutic procedures related to the operation can themselves lead to other complications. A study performed at the Grace New Haven Hospital revealed a 22 percent chance that a patient would suffer an iatrogenic complication during his stay on a medical floor where major surgical procedures were not being performed (*9*). There has been much emphasis in the literature on the risk of wound infection from a given operation, often to the exclusion of other potential complications that may and often do occur, although it obviously makes little difference to the patient whether his prolonged hospitalization is due to a complicating wound infection, a urinary tract infection, or a pulmonary embolus. Therefore, in this report we are concerned with all postoperative complications for patients who underwent

total hip replacement at the Presbyterian-St. Luke's Hospital.

Materials and Methods

Total hip replacement with the use of acrylic cement was started in the Presbyterian-St. Luke's Hospital on December 31, 1968, without laminar airflow in the operating room. We reviewed the charts of all patients who underwent this procedure between December 31, 1968, through December 31, 1970, and allowed a 10-month followup period through October 31, 1971.

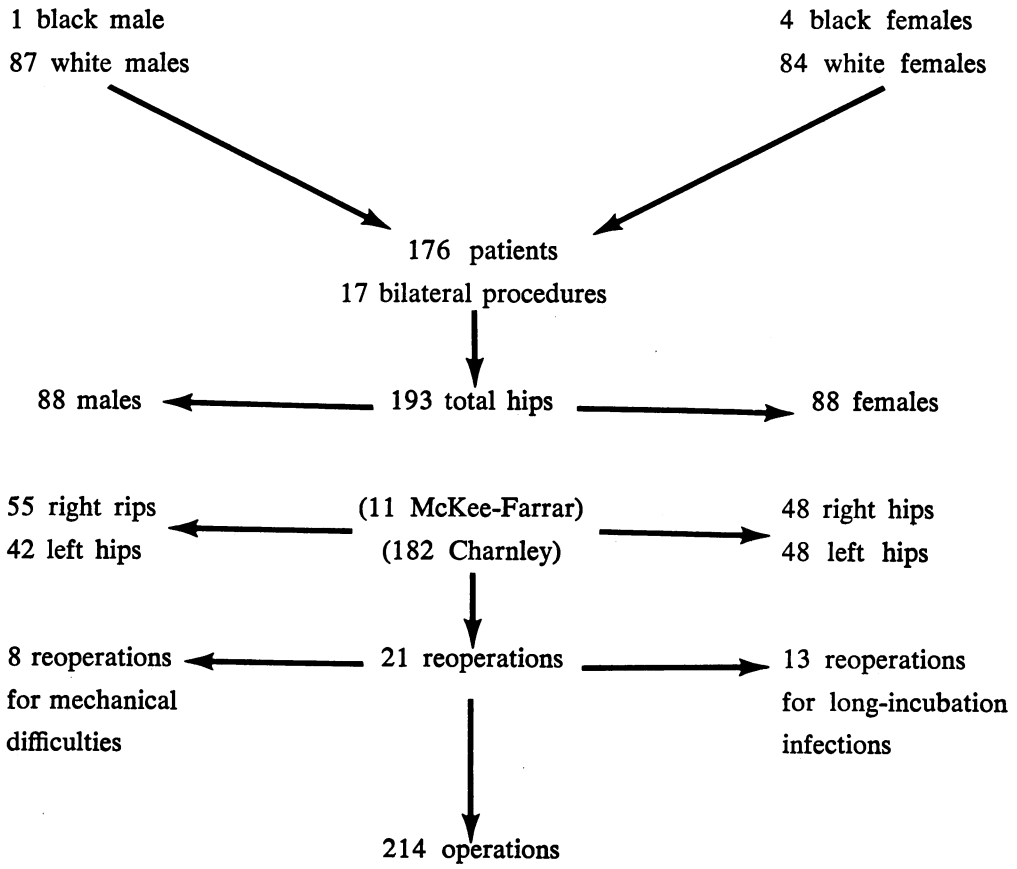
The following criteria were used to establish the presence or absence of a wound infection or a reaction to a foreign body.

Group 1 included patients who were febrile for less than 7 days and had no reaction or drainage at the wound site. Patients were considered febrile if they had an oral temperature of 99° F. or higher and afebrile when their temperature stayed below this level for 48 hours.

Group 2 included patients who were febrile more than 7 days without local reaction or abnormal drainage (other than serous) at the wound site. Patients in this group had unexplained fever, which could have been caused by a reaction to a foreign body, a smoldering wound infection that was not clinically evident and seemingly self-limited, or other undetermined causes.

Group 3 included patients who were febrile for more than 7 days, had a local wound reaction with erythema or tenderness or abnormal drainage, and were judged to be clinically infected. Duration and character of drainage, fever, heat,

Distribution of 176 patients who underwent 193 total hip replacements and 214 operative procedures during study period December 31, 1968–December 31, 1970



NOTE: Followup for reoperation continued through October 31, 1971.

erythema, and clinical response to antimicrobials were considered.

The nurses' notes were found to be the best indicators of the nature and persistence of drainage. They usually described it as brownish, yellowish, purulent, or foul smelling. A patient was considered to have a clinical response to antimicrobial treatment when the agent given was specific for fever that was believed to be to related to local wound reaction and drainage at the wound site, and both these signs disappeared within 5 days after the treatment was started. Two patients with stitch abscesses were also placed in this group. Immediate infections were arbitrarily classified as those occurring during the initial hospitalization within 6 weeks of the operative procedure. Only late wound (deep) infections occurring after this time and subsequently requiring readmission of the patient were monitored.

Results

Demographic data. As shown in the chart, 176 patients received 193 total hip replacements during the 2-year period. Eleven of the replacements were done by the McKee-Farrar procedure and 182 by the Charnley procedure. Twenty of the patients underwent reoperations, making a total of 214 operations (1 patient had 2 additional procedures). There was an equal number of men and women. The women had the same number of procedures performed on the right hip as on the left, whereas the men had 55 procedures on the right hip and 42 on the left.

The average age of the patients was 62.4 years, with no significant difference between sexes. The median age was 64.4 years, the mode was 68 years, and the range was 23 to 86 years. Ninety percent of the patients were over age 50, and 67.6 percent were over age 60.

Causes of hip derangement. The diseases which caused the hip derangements were degenerative arthritis, 134 patients; rheumatoid arthritis, 19 patients; avascular necrosis, 16 patients; slipped epiphysis, 4 patients; Paget's disease of bone, 2 patients; and metastatic cancer, primary site undetermined, 1 patient.

Wound infections. The immediate wound infection rate for the 176 patients who had 201 operative procedures (excluding 12 patients who underwent 13 reoperations for long-incubation (deep) wound infections was 28.3 percent, as shown in the following table.

Classification	*Number of procedures*	*Infection rate (percent)*
Group 1, febrile less than 7 days, no evidence of infection or reaction	40	19.9
Group 2, febrile more than 7 days, unexplained fever	104	51.8
Group 3, febrile more than 7 days, clinical infection	57	28.3
Total	201	100.0

The average time for surgery was 152 minutes for the total hip replacement with acrylic cement in contrast to an average of 95 minutes for placement of an Austin-Moore prosthesis at our hospital.

As the following data show, infection rates were not significantly different whether or not the patient had had previous surgery on the same hip ($X^2 = 1.5$, not significant).

Wound classification group	*Previous surgery*		*Total hip replacements*
	Yes	*No*	
1	6	34	40
2	16	85	101
3	12	40	52
Total	34	159	193

Group 1 patients averaged 5 days of fever; group 2, 15.4 days; and group 3, 18.3 days, as shown in the following table.

Wound classification group	*Days of temperature elevation*		
	99°–100° F.	*More than 100° F.*	*Total days*
1	2.1	2.9	5.0
2	7.0	8.4	15.4
3	8.4	9.9	18.3

Table 1. Wound classification and postoperative use of an indwelling hemovac suction tube in patients who underwent total hip replacement

Wound classification	Total hip replacements	Hemovac suction tube		
		<72 hours	>72 hours	Total
Group 1	40	5	7	12
Group 2	104	15	19	34
Group 3	57	14	14	28
Total	201	34	40	74

NOTE: Use of the hemovac suction tube for any time period resulted in no significant difference between patients in groups 1 and 2 ($X^2 = 0.09$); there was a significant difference between patients in groups 1 and 2 compared with those in group 3 ($X^2 = 5.2$, $P < 0.05$).

The average peak postoperative white blood cell count (WBC) was evaluated. Although the group 3 patients did have higher average counts than groups 1 and 2 patients, the WBC was not helpful for the individual patient. All three groups averaged an elevated WBC—group 1, 12,100; group 2, 12,200; and group 3, 14,400.

An important factor in determining whether a patient would develop a wound infection was the use of a hemovac suction tube. There was no significant difference between use of the hemovac tube for less than or more than 72 hours. However, there was a significant difference in groups 1 and 2 compared with group 3 with any use of the hemovac ($X^2 = 5.2$; $P < 0.05$) (table 1). A hemovac was also used for 9 of 12 of our patients with long-incubation infections; 4 of these patients were in group 2, where the hemovac was used for 34 patients, and 5 in group 3, where 28 patients were similarly treated (table 2).

All organisms enumerated were tabulated only once regardless of the number of times they appeared in repeated cultures on a single patient. Coagulase-positive staphylococci were isolated two times in group 1, once in group 2, and nine times in group 3. However, coagulase-negative staphylococci, gram-negative rods, and enterococci were the most frequent isolates (table 3).

We subdivided group 2 into patients with no obvious explanation for prolonged fever and patients with possible explanations, such as infection at a site other than the wound or thromboembol-

Table 2. Long-incubation (deep) wound infections in 12 patients in groups 2 and 3 [1] who underwent total hip replacement

Months of incubation [2]	Initial hemovac	Isolates		Treatment	
		Initial admission	Readmission	Initial admission	Readmission
Group 2					
13.....	Yes	No growth.....	Coagulase-negative staphylococci.	Tetracycline, ampicillin, sulfonamides.	Cephalothin, surgical revision.
11.....	Yes	Coagulase-negative staphylococci.	....do.....	Tetracycline.....	Oxacillin, surgical revision.
8.....	Yes	No growth.....	....do.....	Ampicillin, cephalothin, tetracycline.	Penicillin, lincomycin, erythromycin, nitrofurantoin, removal of prothesis.
8.....	Yes	Coagulase-negative staphylococci.	....do.....	None.....	Oxacillin, tetracycline, kanamycin, removal of prothesis.
9.....	No	Culture not done.....	Alpha streptococococci..	....do.....	Oxacillin, excision of sinus tract.
Group 3					
6.....	No	Coagulase-negative staphylococci.	Coagulase-negative staphylococci.	....do.....	Oxacillin, surgical exploration.
6.....	Yes	do.....	Coagulase-negative staphylococci, diptheroids, *Bacillus* species.	Oxacillin, nalidixic acid.	Lincomycin, removal of sinus tract.
11.....	No	Gamma streptococci..	Gamma streptococci..	None.....	Penicillin, removal of prosthesis.
7.....	Yes	*Propionibacterium acnes*, coagulase-negative streptococci.	*Propionibacterium acnes.*	Sulfonamides, nalidixic acid.	Erythromycin, cephalothin, 7-chlorolincomycin, reexplored 1 time, subsequent removal of prothesis.
10.....	Yes	No growth.....	Coagulase, negative staphylococci.	Oxacillin.....	Nitrofurantoin, sulfonamides, methicillin, reexplored.
12.....	Yes	Coagulase-negative staphylococci.	Coagulase-negative and positive staphylococci.[3]	Tetracycline.....	Oxacillin, cephalothin, gentamicin, removal of prothesis.
15.....	Yes	Culture not done.....	Coagulase-negative staphylococci and diphtheroids.	Incision and drainage.	Ampicillin, penicillin, oxacillin, removal of prosthesis.

[1] There was no significant difference between groups 1 and 2 patients ($X^2 = 1.2$). There was a significant difference between patients in groups 1 and 2 compared with group 3 ($X^2 = 5.6 < P$ 0.05).

[2] Average incubation period was 9.7 months.

[3] This patient also had a positive smear for acid-fast bacteria but negative cultures for mycobacterium, and the organism producing these results was believed to be a contaminant. He received antituberculosis treatment for 1 month only while awaiting culture results.

Table 3. Organisms appearing as single and mixed isolates by wound classification groups [1]

Organisms	Group 1		Group 2		Group 3		Total
	Single	Mixed	Single	Mixed	Single	Mixed	
Coagulase-negative staphylococci	7	6	6	6	12	33	70
Escherichia coli	0	1	0	1	0	8	10
Klebsiella-Enterobacter	0	2	0	0	0	10	12
Proteus mirabilis	0	1	0	0	0	5	6
Enterococci	0	0	1	2	0	13	16
Diphtheroids	0	2	4	4	0	10	20
Coagulase-positive staphylococci	0	2	1	0	3	6	12
Pseudomonas aeruginosa	0	0	0	0	0	5	5
Bacillus species	1	2	0	1	0	5	9
Alpha streptococci	0	0	1	1	0	4	6
Coliforms	0	0	0	0	0	2	2
Herellea	0	0	0	0	0	4	4
Serratia	0	0	0	0	0	1	1
Proteus vulgaris	0	0	0	0	0	1	1
Gamma streptococcus	0	0	0	0	1	0	1
Propionibacterium acnes	0	0	1	0	0	0	1
Hemophilus parainfluenza	0	0	0	0	0	1	1
Lactobacillus	0	0	0	0	0	1	1
Peptostreptococcus	0	0	1	0	0	0	1
Total	8	16	15	15	16	109	179

[1] Cultures were taken for 19 patients in group 1 (4 showed no growth), 36 in group 2 (16 showed no growth), and 51 in group 3 (3 showed no growth).

ism. No notable differences were observed between these two subgroups in terms of number of patients for whom cultures were made, isolation of coagulase-negative staphylococci, or white blood cell counts. Patients with possible explanations for fever other than the wound site received 5.6 times as many courses of antimicrobials and averaged 3.6 more days of temperature higher than 100° F. than those with no obvious explanation for fever.

Analysis of group 3 patients with single isolates of coagulase-negative staphylococci versus those with mixed isolates revealed no notable difference in type of drainage, presence or absence of multiple site infections, response to antimicrobials, white blood cell counts, or days febrile.

Long-incubation (deep) wound infections. Long-incubation (deep) wound infections averaged 9.7 months before patients were readmitted to the hospital, characteristically with recurrent low-grade fever, drainage, and pain. These symptoms responded to antibiotics but reoccurred when the antibiotics were stopped (table 2).

In 7 of 12 cases, the same species isolated at the time of initial surgery was also isolated subsequently when the patient was readmitted with a late wound infection. For three patients whose initial cultures showed no growth, systemic antimicrobials were being administered at the time of culture. Cultures were not taken for two other patients duing their initial admission. In 9 of 12 patients, coagulase-negative staphylococci were isolated, in 1 patient an alpha streptovoccus, in 1 patient a gamma streptococcus, and in 1 patient, *Propionibacterium acnes*. For six patients the prostheses were removed, for three they were revised, and for three simple exploration and drainage were performed.

Using preselected criteria for wound infections, we found that none of our patients with late wound infections came from group 1, five came from group 2, and seven came from group 3. The chance that a patient in group 1 or 2 would have a late (deep) wound infection was significantly less when compared with group 3 ($X^2 = 5.6$; $P < 0.05$) (table 2).

Several different antimicrobial regimens were given to these patients. Treatment was usually with an antipenicillinase penicillin, such as oxacillin, cephalosporin, or 7-chloro-lincomycin (table 4).

Associated diseases. Associated diseases included 28 patients with heart diseases, 7 with diabetes mellitus, 7 with benign prostatic hypertrophy, 5 with chronic bronchitis, 4 with cancer, 3 with gout, 2 with hypothyroidism, and 9 with other assorted conditions. Three of the patients with chronic bronchitis were admitted with acute exacerbations of that condition—pneumonia developed in one of these patients during the postop-

erative period. Three other patients had community-onset urinary tract infections that were discovered at the time of admission. Three of the patients with benign prostatic hypertrophy subsequently had postoperative urinary retention and required transurethral resection of the prostate. One of the three patients with gout had an acute attack during the postoperative period. Two patients with underlying cardiovascular conditions had postoperative complications—one had congestive heart failure and the other a cerebrovascular accident. Three patients had acute psychoses in the immediate postoperative period.

Underlying diseases did not contribute directly to any other complications. However, 12 patients who were on steroids for treatment of rheumatoid arthritis had a high rate of complications; 10 of these patients had 19 infections—8 wound infections, 3 urinary tract infections, 3 decubiti, and one each of gastroenteritis, pneumonitis, septic arthritis, bacteremia, and a furuncle.

Mortality. There were four deaths in this series in the postoperative period, three of which were related to underlying cardiovascular diseases. Two patients had myocardial infarction which resulted in their demise—one had a cerebrovascular accident, and the other had unrecognized postoperative cholecystitis with complicating peritonitis *(10)*.

Table 4. Antimicrobial regimens for 12 patients who had late wound infections after total hip replacement

Antimicrobial	Number of times administered			
	Prophylaxis [1]	Therapy	Total	Single agent [2]
Methicillin or oxacillin, or both	6	29	35	12
Ampicillin	2	28	30	9
Sulfonamides	14	11	25	7
Cephalosporins	3	9	12	5
Tetracyclines	[3]4	11	[3]15	[4]6
Nitrofurantoin	2	8	10	2
Lincomycin	2	5	7	3
Nalidixic acid	2	5	7	1
Penicillin	1	4	5	4
Polymixin	0	4	4	0
Kanamycin	0	3	3	0
Gentamicin	0	2	2	0
Erythromycin	0	2	2	0
Mandelamine mandelate	1	1	2	1
Isoniazid	0	1	1	0
Paraminosalicylic acid	0	1	1	0
Streptomycin	0	1	1	0
Total	37	125	162	50

[1] Antimicrobials given to prevent infection at any site. [2] Number of times antimicrobial was used as single agent. [3] In 12 additional instances, 1 or 2 doses of tetracycline were given preoperatively for metabolic bone studies. [4] In 7 additional instances, 1 or 2 doses of tetracycline were given preoperatively for metabolic bone studies.

Urinary tract infections. In 90 percent of the urinary tract infections, colony counts were greater than 100,000 per cc of urine. *Escherichia coli, Klebsiella-Enterobacter,* and *Proteus mirabilis* accounted for 70.8 percent of the isolates (table 5). No urine cultures were taken for 10 percent of the patients, but they had significant pyuria and an indwelling catheter in place for at least 3 days. Urinary tract infections were documented in 32.8 percent of the operations (table 6). There was a significant difference in occurrence of urinary tract infections in patients who were catheterized versus those who were not ($X^2 = 74$; $P < 0.0005$), as well as in those who had an indwelling catheter in place more than 72 hours versus those who did not ($X^2 = 30$; $P < 0.0005$) (table 7). The closed drainage system was used. However, personnel often separated the catheter from the bag tube to collect urine specimens, thus negating the effectiveness of the system.

Decubiti. After 14 (7 percent) of the operations, decubiti developed on the buttocks of the patients. These decubiti were not cultured, but they persisted with drainage for a long time. All were considered to be infected. No decubiti occurred in group 1 patients, and no significant difference was noted in occurrence between patients in group 2 (8.6 percent) and group 3 (8.8 percent).

Lower respiratory infections. Lower respiratory infections occurred 13 times (6.5 percent) after the operations (table 6); 12 were pneumonitis and 1 was acute bronchitis. The following data show a significant association between the occurrence of these infections and the use of intermittent positive pressure breathing (IPPB) machines or heated aerosols ($X^2 = 12.6$; $P < 0.001$).

	IPPB or aerosols		
Infections	*Yes*	*No*	*Total*
Yes	10	3	13
No	55	133	188
Total	65	136	201

Although patients usually received the IPPB machine or heated aerosol treatment for more than 3 days, incomplete chart entries precluded

Table 5. Organisms appearing as single and mixed isolates in 55 urine cultures

Organisms	Isolates	
	Single	Mixed
Escherichia coli	18	10
Klebsiella-Enterobacter	8	8
Proteus mirabilis	9	10
Enterococci	1	5
Diphtheroids		1
Coagulase-positive staphylococci	1	
Pseudomonas aeruginosa	4	4
Coliforms	2	2
Serratia	1	1
Proteus vulgaris		2
Non-group A beta hemolytic streptococcus		1
Alcaligenes faecalis		1
Total	44	45

NOTE: Cultures were taken for 41 of 135 patients not recognized as having an infection; 28 cultures showed no growth, and 13 showed growth at $<10^5$ organisms per cc of urine. Of 59 cultures taken for 66 infected patients, 4 showed no growth.

Table 6. Morbidity and mortality rates for 176 patients who underwent 193 total hip replacements and 201 operations [1]

Complications	Occurrence	Rate
Hospital onset infections	**177**	**88.1**
Urinary tract infections	66	32.1
Immediate wound infections	57	28.3
Late wound infections	12	6.0
Lower respiratory infections	13	6.5
Bacteremia	3	1.5
Septic phlebitis	3	1.5
Hepatitis	2	1.0
Decubiti	14	7.0
Miscellaneous	7	3.5
Community onset infections	**8**	**4.0**
Other medical complications:	**36**	**17.9**
Pulmonary emboli	12	6.0
Thrombophlebitis	9	4.5
Hemorrhage secondary to anticoagulants	6	3.0
Miscellaneous	9	4.5
Anesthesia	**3**	**1.5**
Surgical	**29**	**14.4**
Malposition	10	5.0
Removal of prothesis	6	3.0
Sinus tracts	4	2.0
Loose calcific bodies	4	2.0
Miscellaneous	5	2.5
Mortality	**4**	**2.0**

[1] The denominator 201 operations excludes 12 patients with 13 reoperations who were evaluated only for the presence of long-incubation infections and reoperations.

Table 7. Urinary tract instrumentation [1] for less than or more than 72 hours in patients in whom urinary tract infection did or did not develop

Urinary tract infection	Number	Instrumentation (hours)[2]		
		<72	>72	Total
Yes	66	10	39	49
No	135	17	1	18
Total	201	27	40	67

[1] Includes single and indwelling catheterization and cystoscopy.

[2] Instrumentation versus no instrumentation is significant at $P < 0.0005$ ($X^2 = 74$) and instrumentation more than 72 hours versus less than 72 hours is significant at $P < 0.0005$ ($X^2 = 30$).

analysis of the time relationship between administration of these treatments and onset of infections. Thus, a causal relationship could not be determined.

Bacteremia. *Klebsiella* species were isolated from both the lung and bloodstream of a patient with septic bacteremia and clinical evidence of pneumonia. Coagulase-positive staphylococci were isolated from the lung, wound, and bloodstream of another patient with clinical evidence of pneumonia and a wound infection. A third patient had shaking chills and fever on three occasions when his postoperative wound was manipulated. Multiple blood cultures taken for the third patient were negative after he was started on penicillin and kanamycin. *E. coli* was isolated at greater than 100,000 colonies per cc from his urine and wound site, as well as coagulase-positive staphylococci and *Pseudomonas aeruginosa* at the wound site.

Miscellaneous infections. Although the use of intravenous catheters was not recorded on the charts, it was common practice for most patients to receive them for various periods. Phlebitis at the catheter site was recorded for only two patients; no cultures were taken.

Hepatitis occurred in two patients; their test results for hepatitis-associated antigen were positive. One of these patients had been given a blood transfusion during surgery, and his hepatitis incu-

bation period was 6 weeks. The other patient received albumin during surgery, and hepatitis developed 5 months later. Other infections in this category included one abscess of the groin, one pustule on the face, one peridontitis, one septic arthritis, and two cases of gasteroenteritis.

Thrombophlebitis and pulmonary embolism. Thromboembolic phenomena were diagnosed in 20 (9.5 percent) patients (table 6) by criteria similar to those of Harris and associates (*11*), who reported a rate of 39 percent for elective hip surgery patients. Nineteen of our patients were treated with anticoagulants. Six of these patients had thrombophlebitis only, three had thrombophlebitis and pulmonary embolism, eight had pulmonary embolism without physical evidence of phlebitis, one had septic phlebitis, and one had fat emboli. Six patients suffered significant hemorrhage after receiving anticoagulants.

Anesthesia and surgical complications. Anesthesia complications included one patient with a laryngeal ulcer; one patient with a laryngeal spasm at the time of intubation, who had to be resuscitated and whose surgery was canceled; and one patient who had pharyngeal bleeding after traumatic intubation that resulted in hemorrhage and necessitated blood transfusion.

Surgical complications included infection which necessitated removal of the prostheses for 6 patients, fracture of the femur during surgery on 2 patients, malposition of the femur in 10 patients, obturator neuritis and subsequent neurectomy in 1 patient, peroneal palsy in 1 patient, sinus tracts at the wound site in 4 patients, myositis ossificans in 1 patient, and loose calcific bodies in 4 patients.

Preoperative and total hospital stay. All patients with infections had an average preoperative stay of 3.1 to 5.8 days, as shown in the following table.

Condition	Average preoperative days	Average postoperative days
Pulmonary emboli	2.3	11.3
Infections:		
Lower respiratory	3.1	6.6
Immediate wound	3.8	7.1
Urinary tract	4.2	9.6
Miscellaneous	4.5	14.3
Decubiti	5.8	13.0

The patients who underwent total hip replacements and had no complications stayed an average of 21 days. Those with complications stayed an average of 37 days (table 8).

Economic morbidity. The average cost of hospitalization for patients with no complications was $3,150; for those with complications, it was $5,550 (table 8). Thus, the excess cost of hospitalization for patients with complications was $2,400. Patients who underwent total hip replacements without complications had an average stay of 21 days, which is 9 days longer than the usual stay of all other patients, and their cost of hospitalization was about $1,350 more than that for other patients. Our analysis excluded physicians' fees.

Discussion

Charnley and Eftekhar (*8*) stated that they had not seen a high rate of immediate postoperative wound infections. However, they discussed primary healing versus imperfect early healing that includes sloughs in skin, hematomas, and persistent drainage. In their study of 1,700 patients, primary wound healing predominated over defec-

Table 8. Length of hospitalization and average cost for patients with and without complications

Complications	Number	Average stay in days	Average cost of hospitalization per patient [1]	Total cost of hospitalization for all patients [2]
No	67	21	$3,150	$211,000
Yes	119	37	5,550	660,000
Total patients	[3]176	33	$4,950	$871,000

[1] Calculations based on an average $150 per day for Presbyterian-St. Luke's Hospital during the period of this study.
[2] Rounded to nearest $1,000.
[3] 10 patients hospitalized for bilateral hip operation on 2 or more occasions had both complicated and uncomplicated hospital stays.

tive healing. This leads us to assume that, although the rates were not given, defective healing was quite common. They also reported that superficial wound infections that healed without subsequent involvement of the implant were not included in their study.

Charnley and Eftekhar's patients with defective wound healing may have been similar to the ones we placed in part of group 2 and all of group 3. Our group 1 and part of group 2 patients may correspond to Charnley and Eftekhar's patients who had primary wound healing. Length of time for the operation may have contributed to the immediate wound infection rate of 28.3 percent in our patients (*12*). However, contrary to another report (*3*), previous surgery did not increase the wound infection rate.

"Sterile" long-incubation infections have been discussed by Charnley (*5*). These may be either true culture-negative situations with the use of routine bacteriological methods, such as seen in bacterial endocarditis, or it is possible that cultured "nonpathogens" were eliminated from Charnley's data. The isolation of coagulase-negative staphylococci in 9 of 12 of our patients with long-incubation infections, alpha streptococcus in 1, gamma streptococcus in 1, and *P. acnes* in 1 suggests this possibility.

Our findings indicate that isolation of coagulase-negative staphylococci was not necessarily indicative of infection. However, as with prosthetic cardiac valve surgery and the use of ventriculoatrial shunts for hydrocephalus, isolation of the organism and a compatible clinical course for infection may be significant (*1,2*). Coagulase-negative staphylococci organisms may have been introduced in all wounds at the time of surgery. A large inoculum in the presence of a prosthetic device may be more important than just isolation of an organism. Quantitative studies are necessary to resolve this question. The organism may reflect the patient's endogenous flora or may reflect exogenous contamination from a carrier or the environment. The high rate of use of ampicillin and tetracyclines may have contributed to the selection of the coagulase-negative staphylococci observed in the wound infections (*13*). The need for techniques such as laminar airflow to try to decrease the amount of inoculum at the time of surgery may be important, as suggested by Charnley (*5*).

Antibiograms and biotyping may improve our ability to ascertain whether there is any strain variability in the virulence of coagulase-negative staphylococci and whether the strains are endogenous or exogenous (*14*).

Another difficulty in establishing criteria for diagnosis of infections is the possibility of allergic reactions to the acrylic cement. It has been ascertained in dental surgery that if cold is used to activate the cement, a mixture of monomer and polymer is obtained and a local allergic reaction to monomer occurs (*15–21*). In the total hip replacement, heat has been used to activate the cement to form polymer. From the experience in dental surgery, the chances of an allergic reaction should be minimized depending on the completion of the chemical reaction to form polymer. In fact, Charnley argued against an allergic reaction with acrylic cement (*5*). He attributed a reduction in long-incubation wound infection rates, from 8.9 percent to 0.5 percent, to the use of filtered forced air in his surgical suite, as well as improved wound closure techniques. He is attempting to reduce the rate further by the use of impervious material over or under surgical gowns (*5,7*). If the problem was due to a foreign body reaction, a more stable rate should have been observed. Thus, Charnley believes that the previous wound infections were not due to allergic reactions.

The association of the hemovac suction tube with patients in group 3 and with 9 of 12 long-incubation infections is more likely to be an association with an infectious cause. This finding may implicate the hemovac as a predisposing agent or merely indicate that patients with conditions that may predispose them to infections, such as hematomas, were more likely to receive a hemovac.

One can question the significance of "minor infections" such as decubiti, stitch abscesses, pustules, or furuncles. There is evidence, however, that a person with a "minor infectious lesion" has a higher rate of skin colonization and subsequent serious infectious lesions from the organism that is cultured from the "minor" lesion (*22*). Also, when one considers the ecology of the hospital, any minor infectious process, such as a stitch abscess, has epidemiologic significance in terms of potential spread of the organism to nearby patients.

The observed rate of 6 percent for long-incubation (deep) wound infections is minimum. Charnley indicated that long-incubation infections may occur up to 3 years after the initial surgery (*5*). Our followup period ranged from 10 to 36

months. Also, our study included patients who were readmitted to the hospital for treatment. We did not include the patients with long-incubation infections who were treated continuously with antibiotics and not readmitted to the hospital. Moreover, we have cared for patients with long-incubation infections who had their initial surgery at other hospitals, but we did not include them in this study. Thus, it is likely that some of our patients who had their initial surgery at our hospital went elsewhere for followup care.

Patients who have surgery for insertion of prosthetic devices in the hip without the use of acrylic cement have been reported to have immediate wound infection rates of 6–10 percent (*12, 23*). Our ongoing surveillance program has indicated that the insertion of an orthopedic prosthesis at any site, including the hip, results in a wound infection rate of 7.5 percent; the majority of the infections are immediate, occurring in the first 4 weeks after surgery (*24, 25*). We have observed no difference in the wound infection rates associated with protheses when comparing hips with other sites. It is not likely that immediate rates could be lower than those we have cited when one adds the effect of the acrylic cement to that of a prosthesis, and indeed there may be a synergistic effect as far as the occurrence of an infection is concerned. Therefore, one would expect immediate rates greater than 6–10 percent. Arden and associates have reported a superficial wound infection rate of 15.4 percent and a deep wound infection rate of 3.2 percent, with higher rates observed for patients who had surgery for rheumatoid arthritis and lower rates for those who had surery for osteoarthritis (*26*).

In several recent studies with variable followup periods, deep wound infection rates were 0–11 percent, and superficial wound infection rates were 3–7.6 percent (*27–36*). Whether laminar airflow or prophylactic antibiotics can reduce these rates to the level reported by Charnley (*5*) awaits a well-designed prospective study with adequate controls.

The urinary tract infection rate associated with the use of the Austin-Moore prosthesis in our patients has been 11.8 percent, as determined by our ongoing surveillance system (*24,25*). This indicates that patients undergoing total hip replacement with the use of acrylic cement may have a predisposing factor, in addition to catheterization, that contributes to the observed rate of 32.8 percent. Postoperative X-rays on some total hip replacement patients have demonstrated that the acrylic cement sometimes leaks out of the hip joint into the surrounding tissue and may possibly cause thermal trauma to the bladder.

Several patients had urinary or fecal incontinence in the first few postoperative days. This, as well as colonization of decubiti in 7 percent of these patients by gram-negative bacteria from the gastrointestinal tract, may have predisposed them to the gram-negative bacteria that were often cultured from the wound.

It has been shown that length of hospitalization is directly related to complications that develop (*37*). It is difficult to ascertain how much of this is related to the underlying host disease and the length of preoperative hospitalization or to the type of procedure that the patient undergoes, or both. At least one study has shown that complications are fewer in patients who have their preoperative evaluation outside the hospital, have a short hospital stay, and then are discharged as soon as possible (*38*). The patients in our study not only had a protracted postoperative stay but also a significantly prolonged preoperative stay in relation to the kinds of complications they had (see text table, p. 864). The prolonged preoperative stay may allow the bacterial flora that are prevalent in the hospital to colonize in a patient and thus predispose the patient to an infection with a hospital strain of bacteria.

While most complications described in this report are not new, it is our contention that total morbidity and mortality must be collectively evaluated for each operative procedure. All significant complications that occurred in our patients are tabulated in table 6. Fifty-seven of 176 patients had no significant complications, and 119 patients had 257 significant complications. Thus, approximately one in three patients underwent the operation with no significant complications, while approximately two in three patients averaged 2.2 significant complications. Seventy percent of all the complications were hospital-onset infections, and 76 percent of these were due to urinary tract and wound infections.

The history of any new procedure indicates that there will be more complications when the procedure is first introduced than when it is "perfected." Complications from new procedures may best be prevented by a multidisciplinary approach. For the total hip replacement, a team including an

orthopedic surgeon, a rheumatologist, and an infectious diseases specialist would seem appropriate.

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